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# EFFECT OF WATER STABLE AGGREGATES ON FOREST SOIL INTERRILL ERODIBILITY

FINAL REPORT FOR COOPERATIVE AGREEMENT NO.
INT-89386-RJVA
with MONTANA STATE UNIVERSITY
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Co-op Contact: Fred Phillips

# EFFECT OF WATER STABLE AGGREGATES ON FOREST SOIL INTERRILL ERODIBILITY

Draft Final Report to the Intermountain Station
for Agreement No. INT- 89386-RJVA with Montana State University
Department of Civil and Agricultural Engineering,
and Intermountain Station Engineering Technology Research Work Unit.

by
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27 July, 1990

## INTRODUCTION

For many years, scientists have attempted to develop an index of relative soil erodibility using soil properties (Andre and Anderson, 1961; Middleton et al, 1932-1934; Wischmeier and Mannering, 1969) with varying degrees of success. The amount of the soil in water stable aggregates is one property whose relationship to interrill erodibility has not been thoroughly investigated, particularly with respect to forest soils. This report will outline the study procedures, laboratory results and analysis to relate published values of sediment production from simulated rainfall (Trott, 1982; Trott and Singer, 1983) to soil water stable aggregates and other soil properties for 21 California forest and range soils.

An unpublished preliminary analysis by Burroughs showed that the sediment production values for these soils could be related to a "fineness index" developed from soil particle size gradation data. The fineness index did not explain all of the variance in sediment production, and it appeared that the soil's water stable aggregate content might improve prediction of sediment production. If successful, this information might lead to a better method to estimate the relative interrill erodibility of forest soils.

## OBJECTIVES

1. Test the hypothesis that there is a significant correlation between sediment production and a "fineness index" based on particle size gradation.

2. Test the relationship between sediment production and other soil properties, such as published values of clay mineralogy, organic matter, and bulk density, with the view to developing a better method to estimate forest soil interrill erodibility.

3. Explore the relationship between water stable aggregate content and soil interrill erodibility.

## METHODOLOGY

The basic methodology is to use Trott's (1982) data on sediment production from 21 soils and his data on the physical and chemical properties of these soils to develop a reasonably accurate prediction equation for sediment yield. Trott

did not test all 21 soils for their water stable aggregate characteristics. Therefore, we collected soil samples from either the same California locations where Trott's samples were taken, or from a site selected by a soil scientist from the Forest Service or Soil Conservation Service to give us a sample from the same soil series. We used this second set of samples to measure particle size gradation in: 1) a dispersed condition, and 2) in an "undisturbed" condition using wet sieving to determine the water stable aggregate content. Our purpose was to gather more detailed information on the physical characteristics of these 21 soils to help explain differences in their interrill soil erodibility.

## Dispersed Particle Size Analysis

A large bulk soil sample was carefully split and sieved to give about 500 g of -2 mm material for measurement of organic matter content and particle size gradation of dispersed soils using USDA-SCS (1972) standard methods. There were three exceptions to these standard methods: 1) a 35 gram soil sample was used instead of the 10 gram sample in the SCS procedures. We felt that the larger sample would give a smaller error in measurement of weights in all particle size classes for fine-textured and coarse-textured soils; 2) a soil dispersing chemical was added to the soil sample immediately following digestion of organic material with $H_2O_2$, instead of oven drying to determine the weight of organics. We feel that oven drying prior to dispersing of the soil will reduce the effectiveness of the dispersant by increasing the strength of soil aggregates. We also recognize that without a baseline ovendry weight prior to soil dispersing, then all errors in weight will accumulate in the calculation of the organic matter weight. But, we view an accurate measurement of organic matter as less important than an accurate determination of soil particle size gradation; 3) samples were agitated following addition of the dispersant by inverting each bottle 10 times every half hour for four hours. We have found that this type of sample agitation gave three to five percent more material passing each sieve size than overnight agitation with an oscillating table. The dispersed sample was then washed through the a nest of sieves and the -#200 material was used for a pipet analysis of the fine particle sizes.

## Undispersed Particle Size Analysis to Determine Water Stable Aggregates

Techniques found in the literature to determine the water stable aggregate content of soils are derived from Yoder (1936) with modifications introduced by Kemper and Koch (1966) and Kemper and Rosenau (1986). Kemper's procedure uses the 1-2 mm particle size to characterize water stable aggregate content for a soil. Kemper's procedure also uses an aerosol produced by a humidifier to slowly and carefully wet the soil sample. This maintains the integrity of soil aggregates but does not represent soil wetting under field conditions where rainfall can cause very rapid wetting, in addition to the physical breakdown of aggregates by raindrop impact. In this study, we used six particle size classes with each soil sample saturated by capillary wetting as a compromise between vapor wetting and direct wetting.

A separate set of samples was separated from the bulk supply to determine water stable aggregate content for each sieve size: #16 (1.18 mm), #30 (0.6 mm), #50 (0.3 mm), #100 (0.15 mm), #200 (0.075 mm), and #270 (0.05 mm). For each sieve size, replicate soil samples were prepared and placed in eight numbered sieves,

each with a corresponding numbered collection cup. The loaded sieves and their cups were placed in a sieve holder in a machine designed to raise and lower all eight sieves, each in their own water bath. The holder was placed at the bottom of its vertical stroke and distilled water was added to each cup until capillary action began to wet the soil. When each soil was saturated, usually after about 15 minutes, more distilled water was added to each cup until the soil was just covered. A motor raised and lowered the sieves vertically at 35 cycles per minute with a stroke of 1.3 cm for three minutes plus or minus 5 seconds (Kemper and Rosenau, 1986). After agitation, the material passing and remaining on each sieve was collected separately, oven dried, and weighed to determine the percent of water stable aggregates in each sieve size. This process was repeated for the next sieve size. No further particle size separations were performed on the -#270 material.

Water stable aggregate tests were initially run using a 4 g sample in each replicate sieve. In checking test results with duplicate samples, we became suspicious that 4 g was too much soil for efficient sieving through sieve with an inside diameter of 3.7 cm, particularly for the four smallest sieve sizes. Separate tests with a range of sample weights for each of these sieves verified that the soil sample size should be reduced for the smaller sieves. A soil sample size of 4.2-4.6 g was used for the #16 and #30 sieves, 2.0-2.5 g for the #50 and #100 sieves, and 1.0-1.5 g were used for the #200 and #270 sieves. A balance accurate to 0.001 g was used to weigh samples from the two largest sieves,and samples from the four smallest sieves were weighed with an analytical scale accurate to 0.0001 g.

In this study we used the <u>difference</u> in the percent by weight passing each sieve, as determined from the dispersed and water stable aggregate tests, to measure the aggregate content for that particle size. Six size classes provide important information on the distribution of aggregates by size to improve future development of physical process models of soil detachment and transport.

## Water Repellency

In our laboratory work, we also noted that three soils were difficult to saturate by capillary action, which indicated some degree of water repellency. To test which soils might be water repellent and thus influence our measurements of water stable aggregate content, we used the water drop penetration test as described by DeBano (1981). We placed several drops of distilled water on the surface of each soil and measured the average time for the drops to penetrate the surface. All soils but four had drop penetration times less than 10 seconds. The Josephine soil had a time of 20 seconds, but this was not considered to show significant water repellency. Three soils, Crozier, McCarthy, and Windy, had drop penetration times greater than three minutes and were considered to be water repellent. The water stable aggregate content of these three soils was remeasured using 10 ml of a 3 percent solution of sodium laurel sulfate as a wetting agent in the capillary wetting phase of this procedure. The additional 30 ml of distilled water used to cover the soil resulted in about a 0.7 percent solution of sodium laurel sulfate used for the agitation phase. This chemical caused the soil to saturate immediately, but also caused a greatly reduced water stable aggregate content. It appeared that the chemical caused some aggregates to disperse, and the use of the wetting agent was abandoned.

# DATA ANALYSIS

Data plotting and linear regression techniques were used to develop relationships between particle size gradation, both dispersed and aggregated analysis, and sediment production. The analysis concentrated upon correlation between sediment production as the dependent variable and two gradation indices developed from dispersed particle size data and aggregated particle size data, together with other soil properties as independent variables.

Trott (1982) and Trott and Singer (1983) comment on the water repellency of the Crozier, McCarthy, and Windy soils and speculate on the influence that this property might have had on measurements of sediment production from their simulated rainfall tests. Based on data plotting (figure 1), it is very likely that the sediment production measured by Trott for the these soils was significantly reduced by water repellency. For this reason, data from these three soils were not used in our analysis of relative interrill erodibility. The Appendix gives the dispersed and water stable aggregate curves for each of the 18 soils used in data analysis.

Data plotting showed that a curve form using a quadratic equation with percent fines (dispersed procedure) as the independent variable fit the sediment production data reasonably well. Major deviations from the basic parabolic curve appeared to be caused by two different clay mineralogies: soils with a high smectite clay content plotted above the curve, and soils with a high kaolin clay content plotted below the basic curve. Minor deviations away from the basic curve appeared to be associated with soil bulk density, as measured in Trott's rainfall simulator pans. Neither organic matter content, iron sesquioxide content (dithionite iron), nor any other chemical constituent appeared to be correlated with sediment production, as determined by data plotting.

Trott's measurements of sediment production were made using -4 mm soil packed into soil boxes 0.6 m on a side. However, Trott only provides dispersed particle size gradation data for the -2 mm fraction of each soil. An earlier report by Howard et al (1979) gives the 2-4 mm gravel content for 14 of the 21 soils used in Trott's tests. A close examination of the 2-4 mm gravel content for 11 of the 18 soils used in the statistical analysis showed that this variable was not correlated with deviations from the basic curve in Figure 1.

Two stepwise linear regression analyses were performed on the 18 "wettable" soils, the first using a fineness index based upon dispersed particle size gradation data, and the second using the index based upon aggregated particle size data. Variables initially believed to be important were perecnt fines, percent smectite clay, percent kaolin clay, and bulk density. The backward elimination stepwise procedure dropped bulk density as a significant variable. With all variables significant at the 95% confidence level (see Table 1), the resulting equation to predict sediment yield is:

$$SY = -9.391 + 25.298\,(Si+Cl) - 0.2297\,(Si+Cl)^{2} - 12.551\,(Kaolin) + 31.420\,(Smectite). \qquad Adj.\ R^{2} = 0.905$$

Where: SY = Sediment production in grams per square meter.
Si+Cl = Percent fines = percent silt plus percent clay (dispersed procedure).

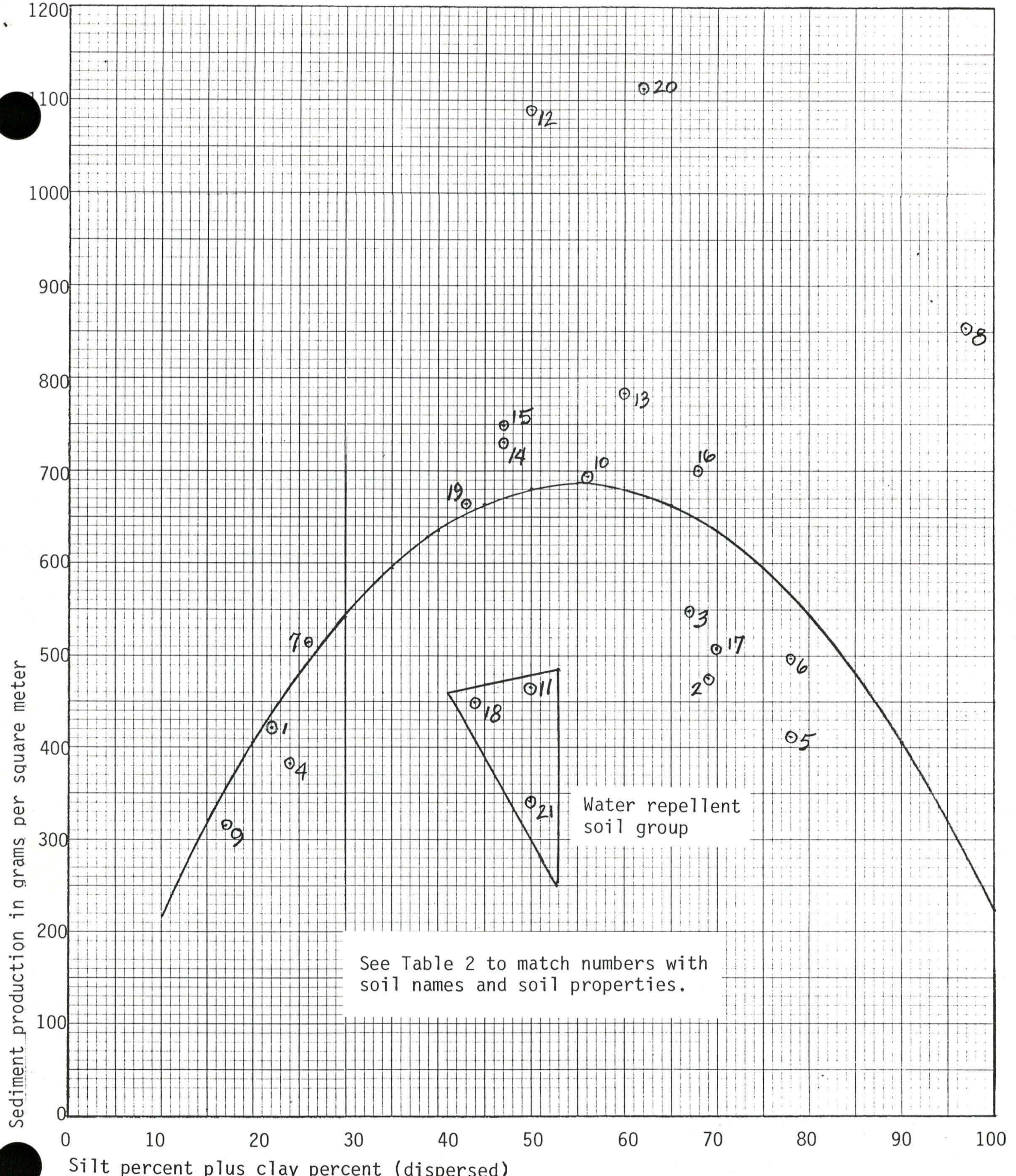


Figure 1 -- Sediment production ($g/m^2$) as a function of silt plus clay content (dispersed)

Table 1--Analysis of variance for stepwise linear regression.

| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 4 | 817039.5105 | 204259.8776 | 41.462 | 0.0001 |
| Error | 13 | 64043.6005 | 4926.4308 | | |
| C Total | 17 | 881083.1111 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 70.1885 | R-Square | 0.9273 |
| Dep Mean | 636.2222 | Adj R-sq | 0.9049 |
| C.V. | 11.0320 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for $H_0$: Parameter=0 | Prob > :T: |
|---|---|---|---|---|---|
| INTERCEPT | 1 | -9.3908 | 88.1572 | -0.107 | 0.9168 |
| (SI+CL) | 1 | 25.2980 | 3.5122 | 7.203 | 0.0001 |
| (SI+CL)**2 | 1 | -0.2297 | 0.0338 | -6.792 | 0.0001 |
| KAOLIN | 1 | -12.5506 | 5.3489 | -2.346 | 0.0355 |
| SMECTITE | 1 | 31.4202 | 4.3890 | 7.159 | 0.0001 |

Table 2 lists the soils by name and number (refer to Figure 1), the values for each of the independent variables, the observed (Trott) and predicted sediment production using the above equation.

The same analysis using aggregated particle size data gave a lower adjusted R**2 and much larger residuals. Therefore, the use of a fineness index based on aggregated particle size data for predicting sediment production is not recommended.

## DISCUSSION

Data analysis shows that the prediction equation provides a reasonably accurate model to estimate interrill sediment production of -4 mm soil using percent fines (dispersed) of the -2 mm fraction and clay mineralogy as independent variables. We hypothesized that the parabolic curve shape in Figure 1 is the effect of increasing soil aggregation with increasing fine particle content in the soil as measured by the dispersed technique. The mechanism appears to be that as the amount of soil aggregation increases, the soil increasingly behaves as a coarser-textured material, with a corresponding decrease in sediment production. We used the soil samples collected by the Forest Service and performed the two laboratory procedures at Montana State University, Department of Civil and Agricultural Engineering, and the Forestry Sciences Laboratory in Moscow, Idaho. The percent fines for each procedure and the water stable aggregate content for each soil are given in Table 3. Figure 2 shows the water stable aggregate content for each soil plotted against the percent fines as measured by the dispersed laboratory procedure. Since the water stable aggregate content increases with increasing percent fines, we can accept the hypothesis that aggregated soils do behave as a "coarse-textured" soil and that sediment production decreases as the amount of soil aggregation increases.

The laboratory procedure used in this study to measure the amount of aggregation for each soil apparently works well. That is, it measures those aggregates that are stable during the wet sieving process, but the stability of these aggregates exposed to rainfall impact is a function of clay mineralogy. Those soils with significant amounts of smectite clay appear to have aggregates that are easily broken down by raindrop impact, which accounts for the increased sediment production from these soils. Soils with kaolin clays appear to have slightly stronger aggregates and a slightly reduced sediment production.

Sediment production predicted by the equation is for the -4 mm soil in small interrill areas. The effect of 2-4 mm gravel on sediment production could not be tested by statistical analysis because the gravel content was not given for all 21 soils. We recognize that the amount of coarse fragments can effectively reduce sediment detachment and transport, but other data will have to be used to measure this effect.

It is extremely important to recognize that sediment production in grams per square meter from this report does not represent sediment production that will be produced by a natural storm of the same duration and intensity. But, the prediction equation can be used to develop a relative scale of erodibility for the -4 mm "matrix" of soil between large coarse fragments. Development of this relative erodibility scale will be covered in the next section.

Table 2 -- Values of variables (Trott's data) used in the analysis of variance with observed and predicted values of sediment production, SY.

| SOIL NO. | SOIL NAME | PARENT MATERIAL | SY $g/m^2$ | Si+Cl % | Kaolin % | Smectite % | SY Pred. |
|---|---|---|---|---|---|---|---|
| 1 | Ahwahnee | Granitic | 421 | 22 | 2 | 0 | 411 |
| 2 | Aiken | Volcanic | 475 | 69 | 13 | 0 | 479 |
| 3 | Argonaut | Metavolcanic | 549 | 67 | 6 | 3 | 673 |
| 4 | Auberry | Granitic | 383 | 24 | 3 | 0 | 428 |
| 5 | Auburn | Metavolcanic | 411 | 78 | 18 | 2 | 403 |
| 6 | Auburn Var. | Metavolcanic | 497 | 78 | 8 | 4 | 592 |
| 7 | Chewanakee | Granitic | 514 | 26 | 4 | 1 | 474 |
| 8 | Contra Costa | Sandstone and shale | 855 | 97 | 6 | 19 | 805 |
| 9 | Cagwin | Granitic | 314 | 17 | 0 | 0 | 354 |
| 10 | Corning | Mixed rock alluvium | 693 | 56 | 2 | 4 | 788 |
| 11 | Crozier[1] | Andesitic breccia | 467 | 50 | 4 | 0 | - |
| 12 | Ditchcamp | Basalt | 1090 | 50 | 1 | 14 | 1109 |
| 13 | Hillgate | Sedimentary alluvium | 785 | 60 | 4 | 4 | 757 |
| 14 | Holland | Granitic | 730 | 47 | 5 | 3 | 704 |
| 15 | Hurlbut | Metasediments | 749 | 47 | 3 | 0 | 635 |
| 16 | Forbes/Ina | Peridotite | 701 | 68 | 2 | 0 | 624 |
| 17 | Josephine | Metasediments | 509 | 70 | 12 | 0 | 485 |
| 18 | McCarthy [1] | Volcanic alluvium | 450 | 44 | 3 | 0 | - |
| 19 | Musick | Granitic | 664 | 43 | 7 | 2 | 629 |
| 20 | Packwood | Basalt | 1112 | 62 | 1 | 14 | 1103 |
| 21 | Windy [1] | Volcanic alluvium | 341 | 50 | 2 | 2 | - |

[1] Data from these soils were not used in the analysis because of water repellency that may have influenced measurement of sediment production.

Table 3 --Water stable aggregate content of 18 California soils, based on the Forest Service collection of soils used by Trott.

| SOIL NO. | SOIL NAME | (1) Silt + Clay DISPERSED % | (2) Silt + Clay AGGREGATE % | (3) = (1) - (2) WATER STABLE AGGREGATE CONTENT |
|---|---|---|---|---|
| 1 | Ahwahnee | 28 | 10 | 18 |
| 2 | Aiken | 66 | 14 | 52 |
| 3 | Argonaut | 67 | 13 | 54 |
| 4 | Auberry | 29 | 10 | 19 |
| 5 | Auburn | 64 | 18 | 46 |
| 6 | Auburn Var. | 74 | 18 | 56 |
| 7 | Chewanakee | 28 | 8 | 20 |
| 8 | Contra Costa | 58 | 6 | 52 |
| 9 | Cagwin | 24 | 8 | 16 |
| 10 | Corning | 43 | 19 | 24 |
| 11 | Crozier [1] | 48 | - | - |
| 12 | Ditchcamp | 53 | 10 | 43 |
| 13 | Hillgate | 63 | 14 | 49 |
| 14 | Holland | 37 | 5 | 32 |
| 15 | Hurlbut | 58 | 15 | 43 |
| 16 | Forbes/Ina | 68 | 5 | 63 |
| 17 | Josephine | 70 | 5 | 65 |
| 18 | McCarthy [1] | 49 | - | - |
| 19 | Musick | 42 | 15 | 27 |
| 20 | Packwood | 63 | 16 | 47 |
| 21 | Windy [1] | 46 | - | - |

[1] Lab results not reliable for these water repellent soils.

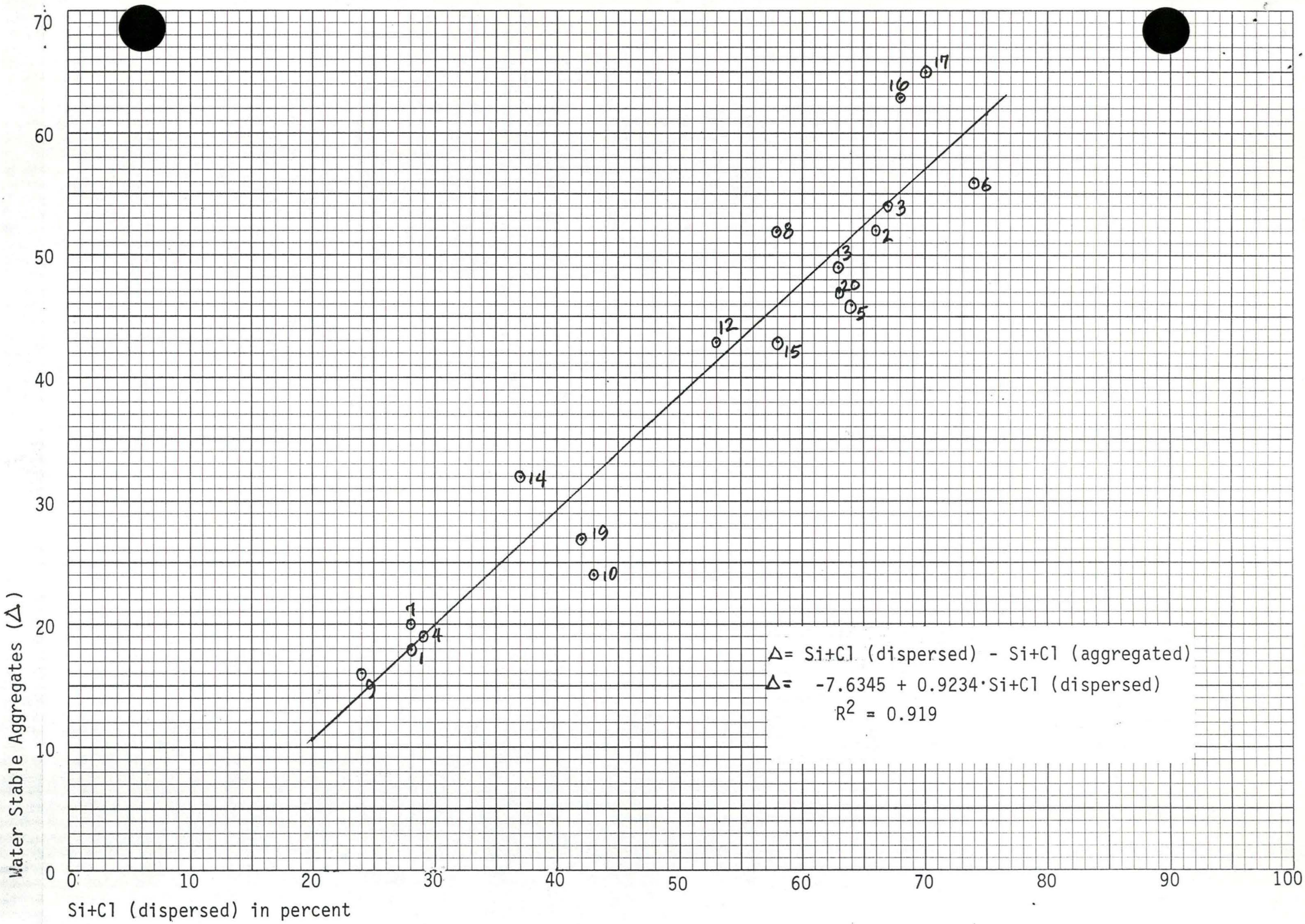


Figure 2 -- Water stable aggregate content as a function of percent silt plus clay (dispersed).

# APPLICATIONS

The results of this study form the basis for estimating the relative interrill erodibility of soils in catchment scale sediment yield models, such as the "Guide for predicting sediment yields from forested watersheds" (Cline and others, 1981). This publication is often referred to as the R-1/R-4 Guide. The use of Trott's data and the prediction equation given in this report to develop a scale of relative erodibility is the most efficient use of this information for several reasons. All of Trott's measurements were made on the same size plot, with the same slope (9%) and rainfall intensity. Differences in sediment production were caused solely by differences in soil properties.

To convert sediment production in grams per square meter from Trott's study to relative erodibility as used in the R-1/R-4 Guide, select some soil or geologic parent material as a "base". Then, use its sediment production, as estimated from the prediction equation, as a divisor to place sediment production from other materials on a relative scale. For example, select the coarse-textured Cagwin soil, derived from granitic parent material (Table 2), as the base. Divide all the sediment production values by that for the Cagwin soil (354 $g/m^2$). The relative erodibility for Cagwin is 1.0 and 2.0 for the finest-textured granitic soil, Holland, and 3.1 for the Packwood soil. This gives the relative erodibility for the -4 mm portion of the soil. Additional information on the effects of coarse fragments will be required to adjust the interrill -4 mm soil relative erodibility to a representative value for the total soil.

Ongoing work within the Intermountain Station's Engineering Technology project will relate the results given in this report to sediment production from Forest Service rainfall simulator trials by adjusting for slope gradient, coarse fragment content, and applied kinetic energy. This process will be used to validate and extend the results of this report to soils in the northern Rocky Mountains. This effort will result in a general equation to estimate interrill detachment coefficients for use in the Forest Service deterministic sediment production model currently under development.

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# APPENDIX

Particle size gradation curves, dispersed procedure and aggregate procedure, for the Forest Service collection of the 21 California soils used by Trott.

MONTANA STATE UNIVERSITY
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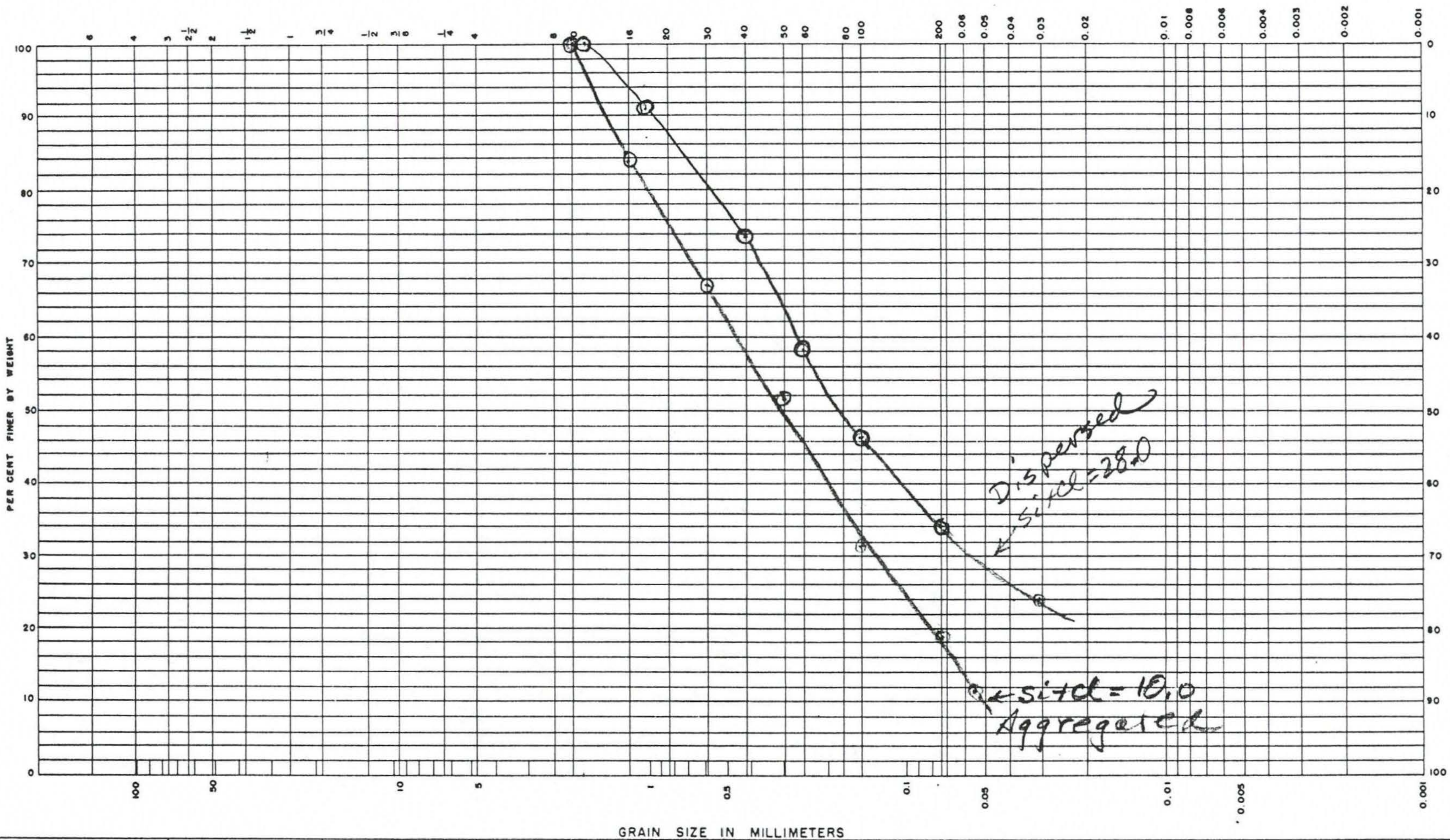
# GRADATION CURVE

BY__________ LABORATORY NO.__________
DATE__________ FIELD NO.__________

| SIEVE ANALYSIS | | HYDROMETER ANALYSIS |
|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH - U.S. STANDARD | GRAIN SIZE IN MM |

AHWAHNEE




| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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DEPARTMENT OF CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

GRADATION CURVE

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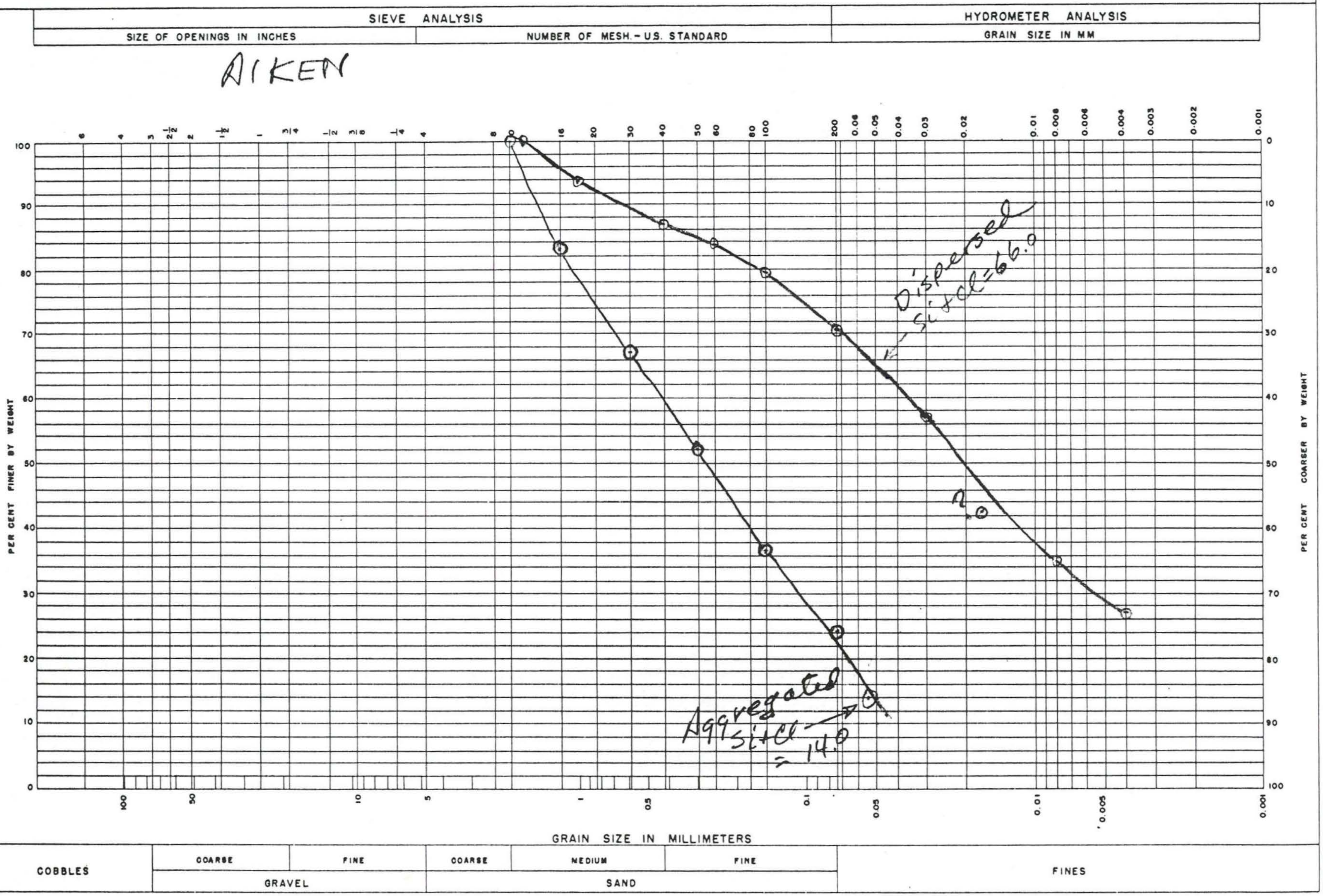
DATE ________ FIELD NO. ________



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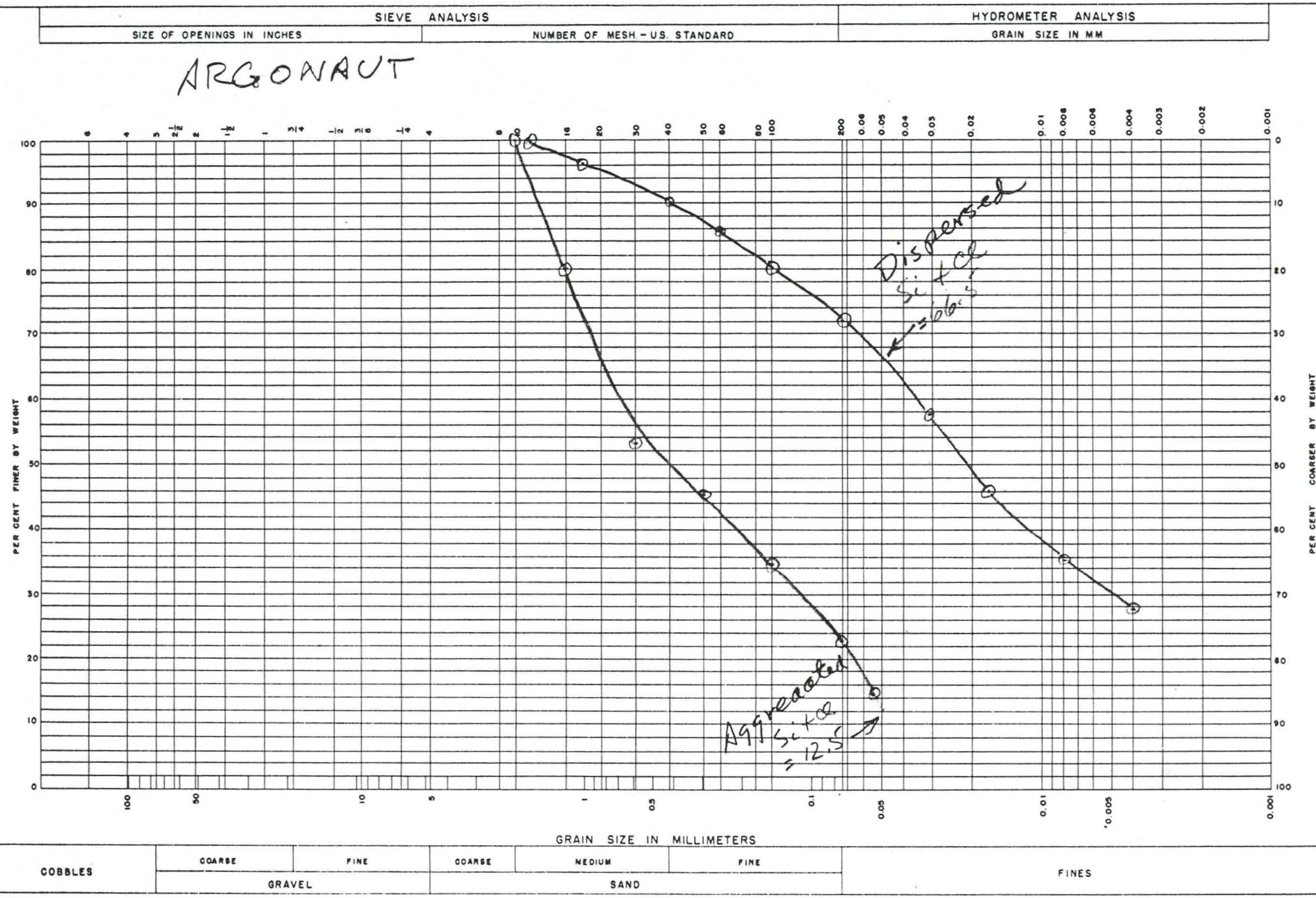

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SOIL MECHANICS LABORATORY

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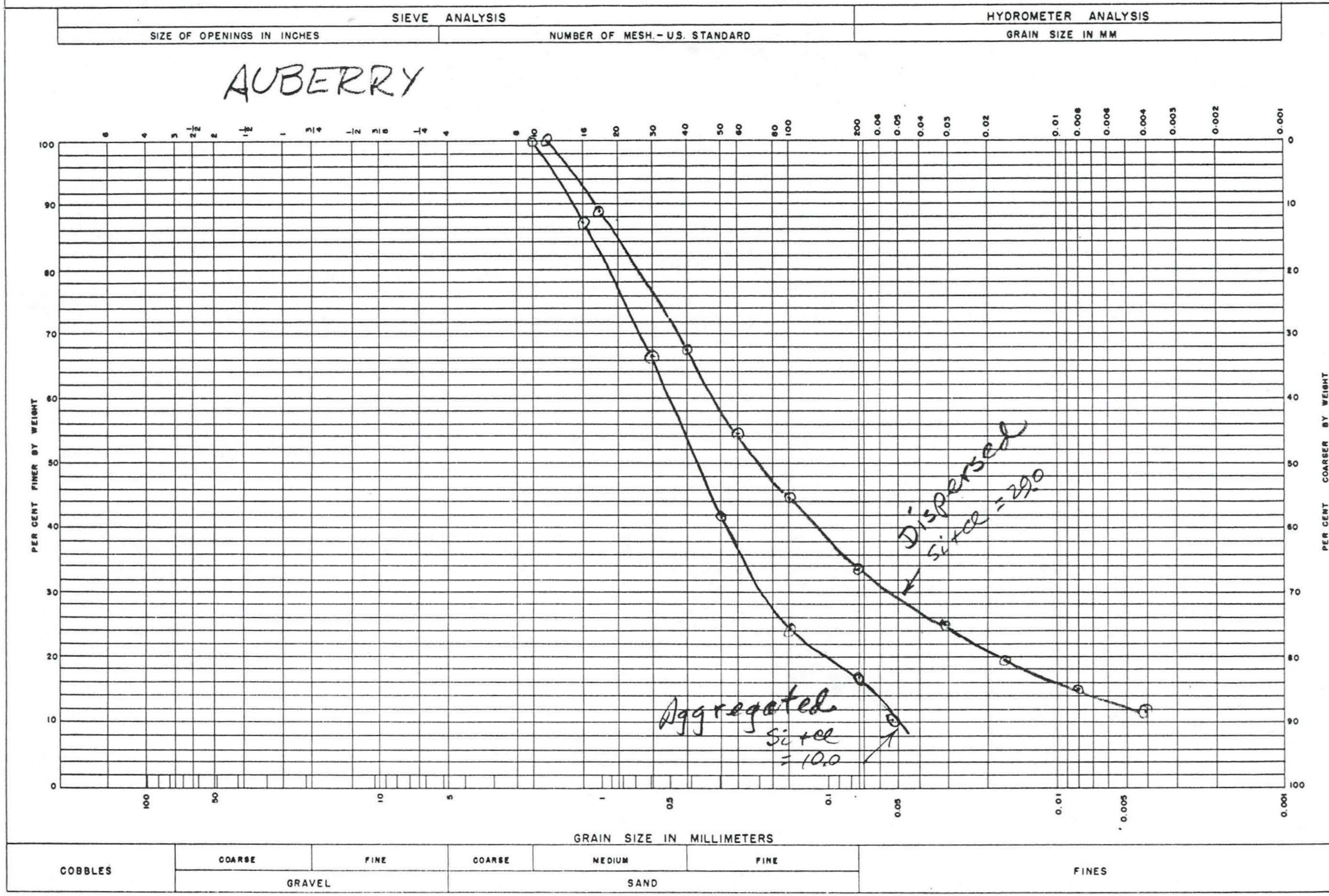

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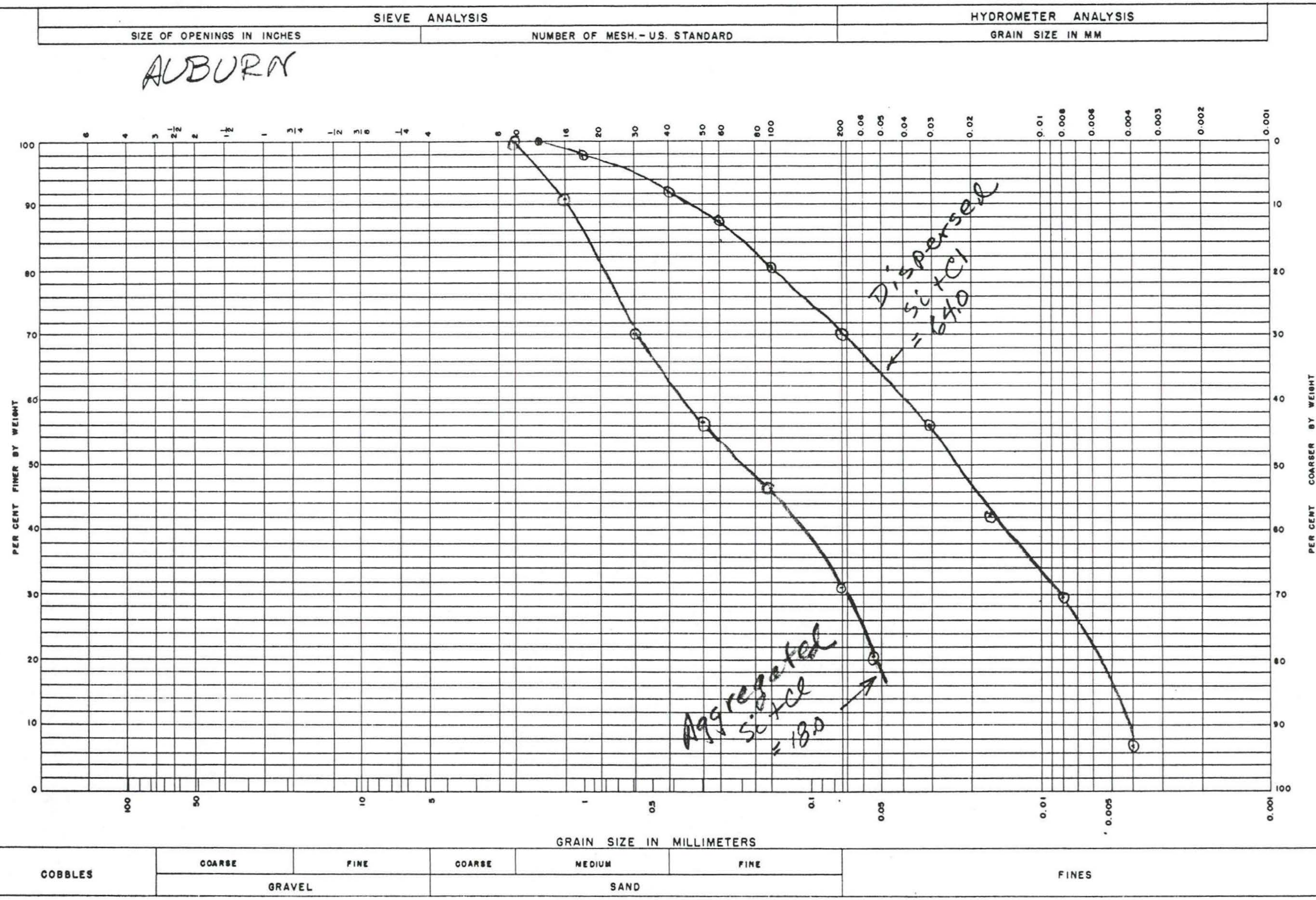

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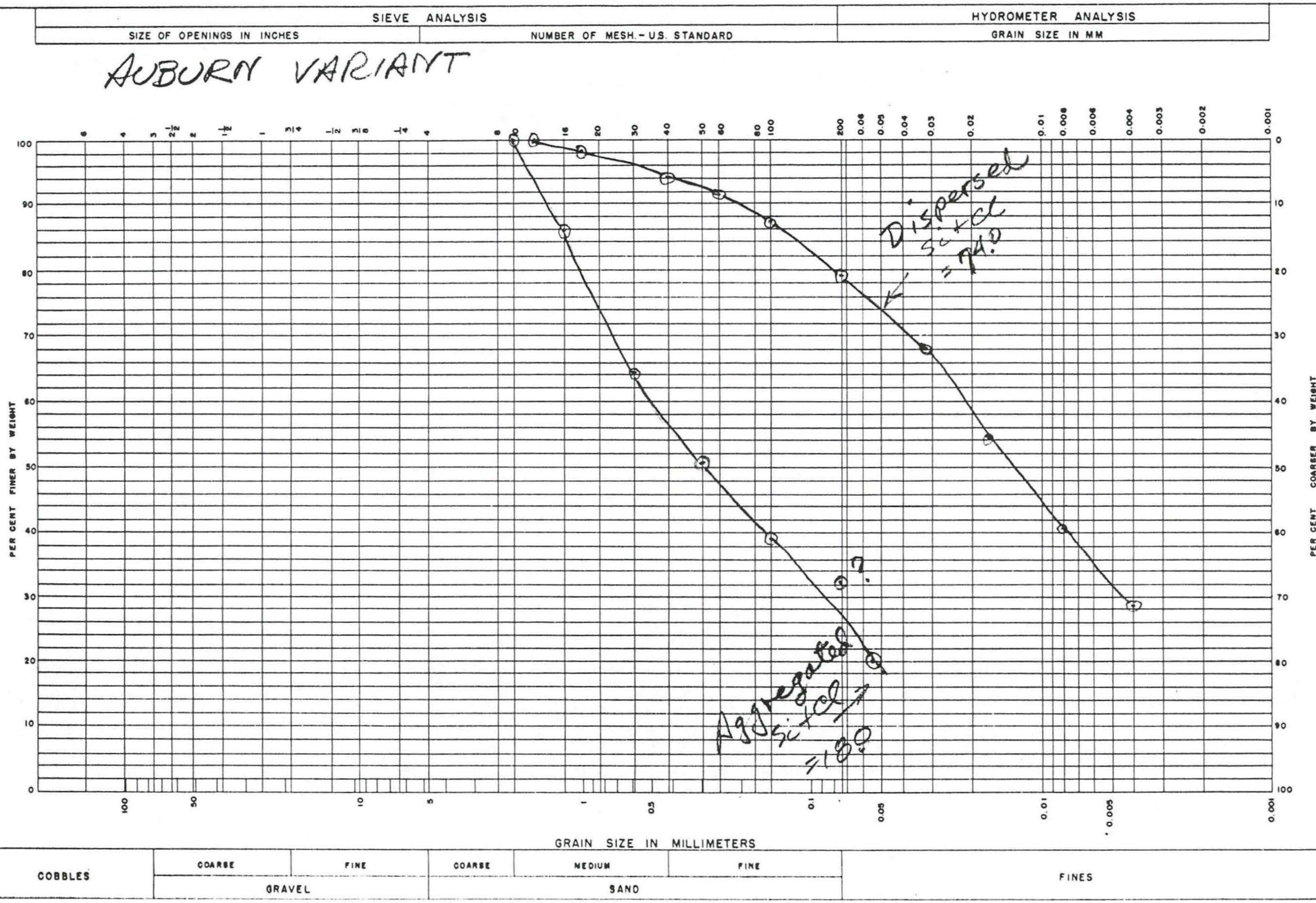

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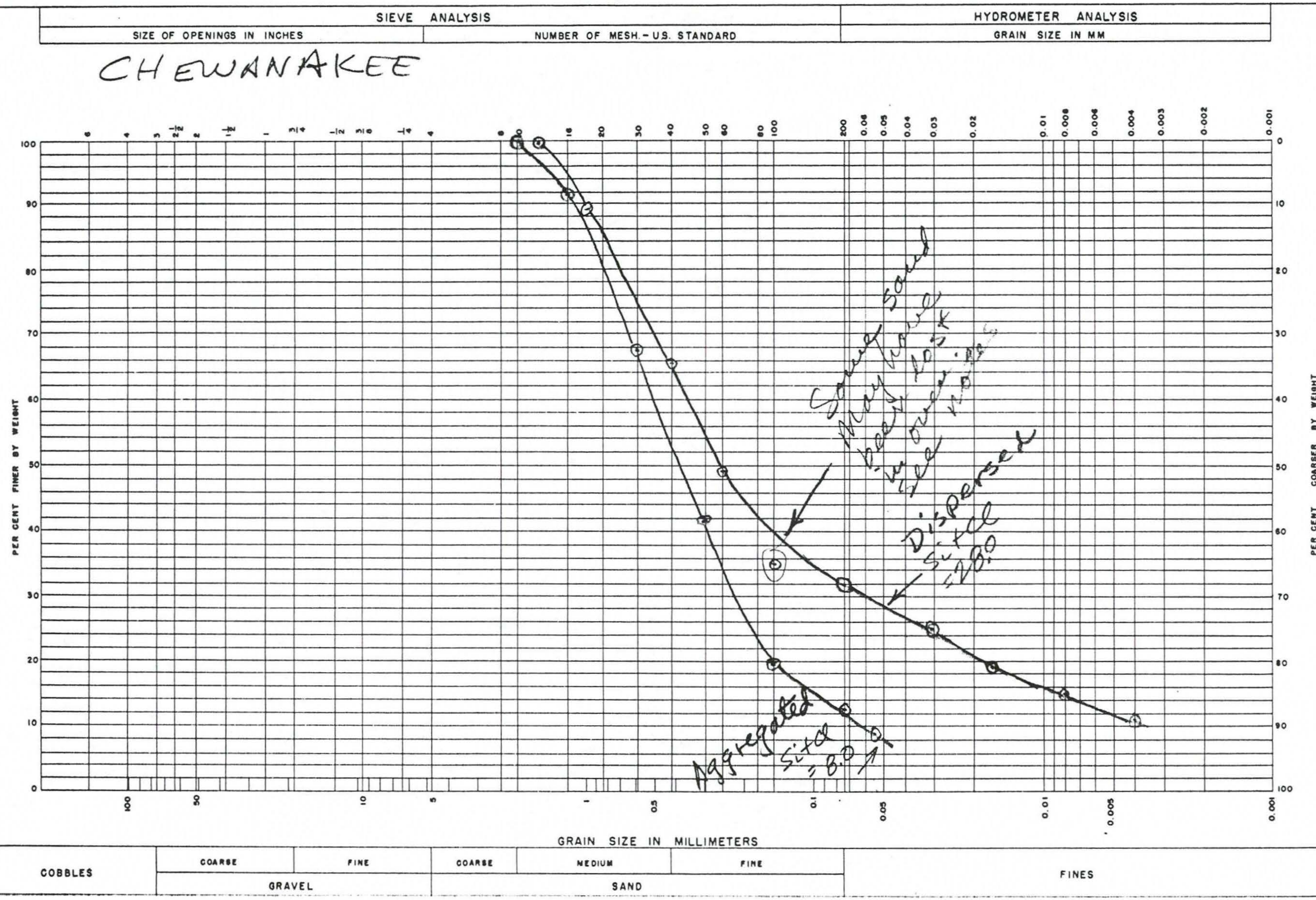

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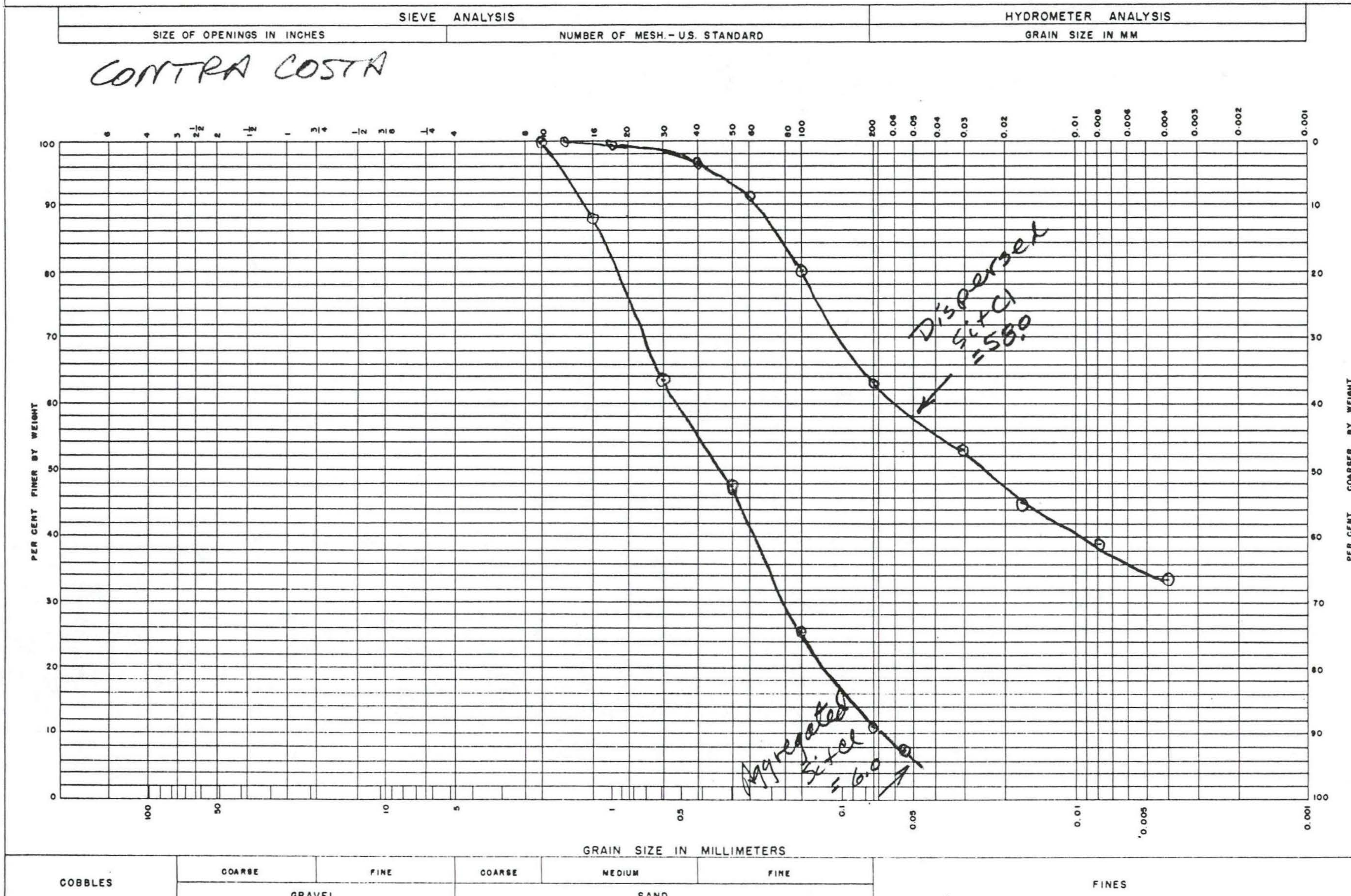

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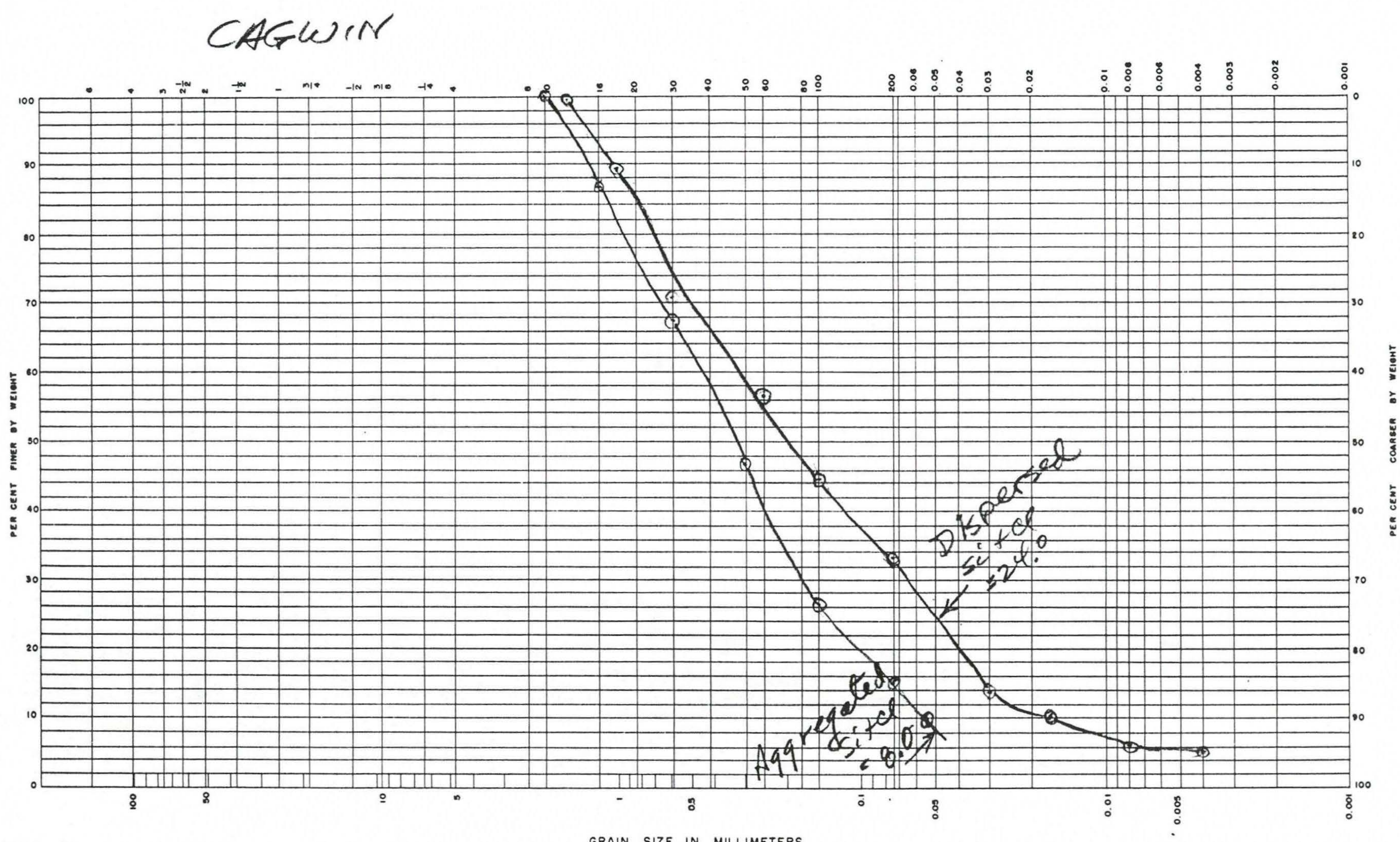
SOIL MECHANICS LABORATORY

GRADATION CURVE

BY__________ LABORATORY NO.__________
DATE__________ FIELD NO.__________

| SIEVE ANALYSIS | | HYDROMETER ANALYSIS |
|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH.- U.S. STANDARD | GRAIN SIZE IN MM |




| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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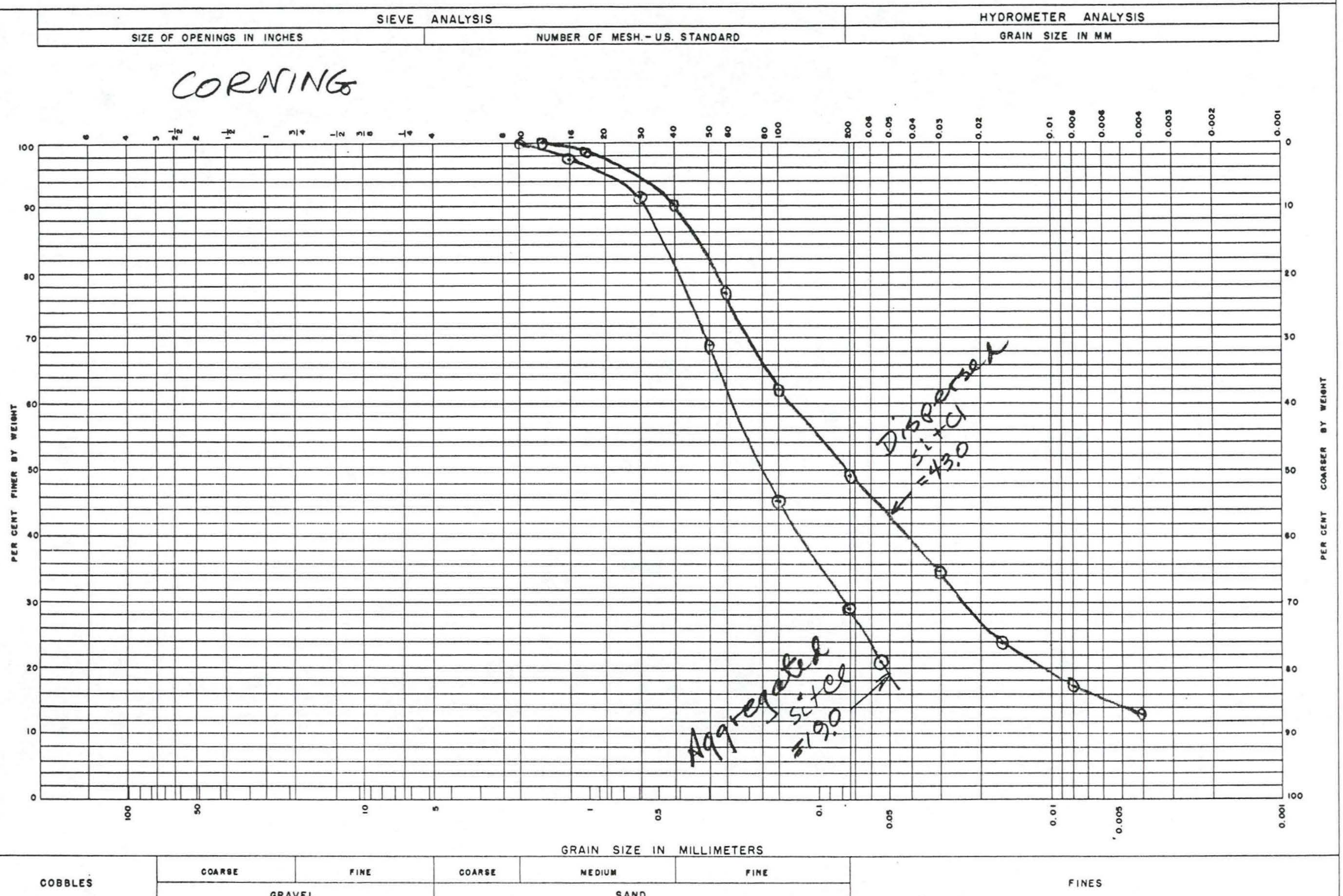
GRADATION CURVE

BY ______ LABORATORY NO. ______
DATE ______ FIELD NO. ______



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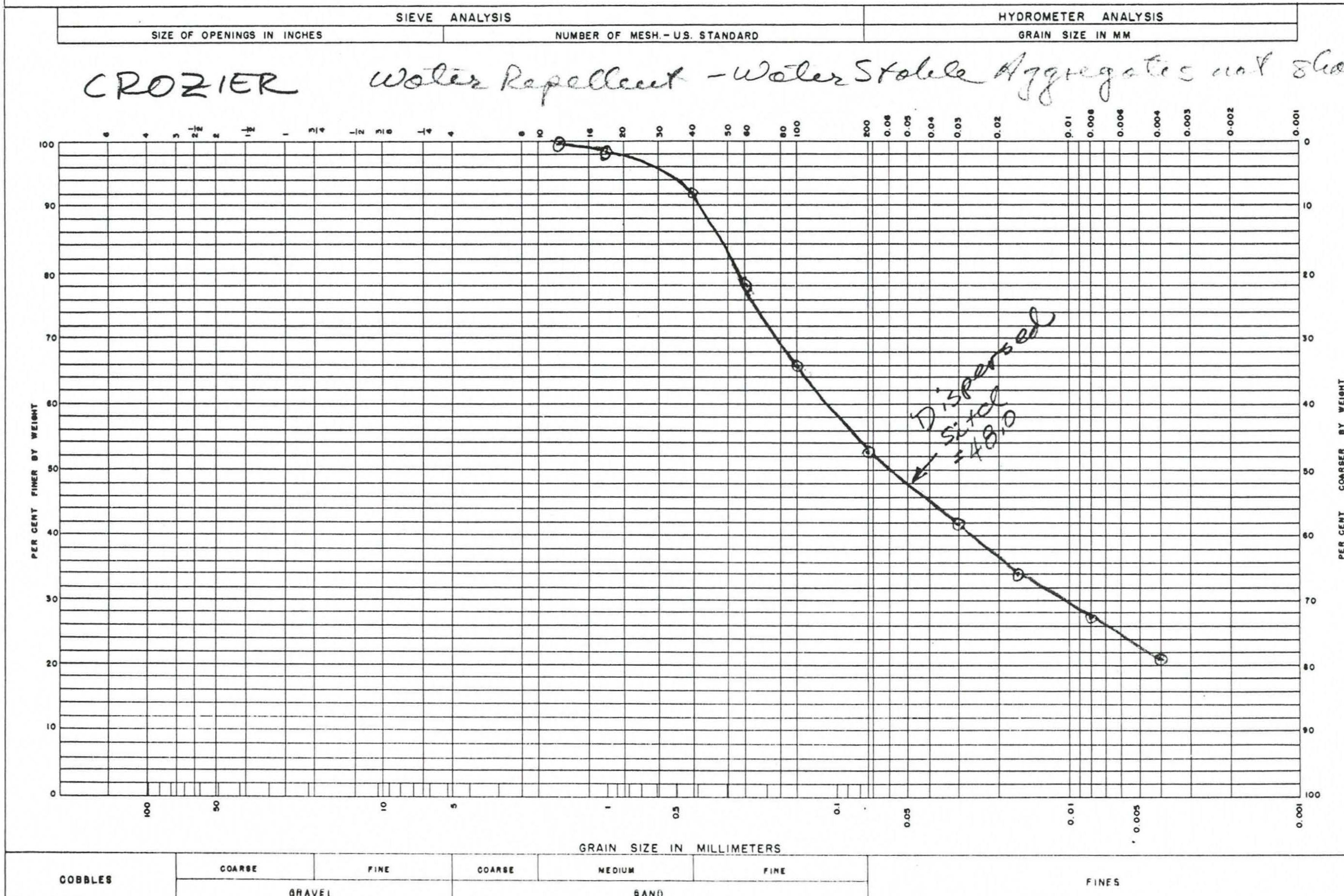
SOIL MECHANICS LABORATORY

# GRADATION CURVE

BY ____________ LABORATORY NO. ____________

DATE ____________ FIELD NO. ____________



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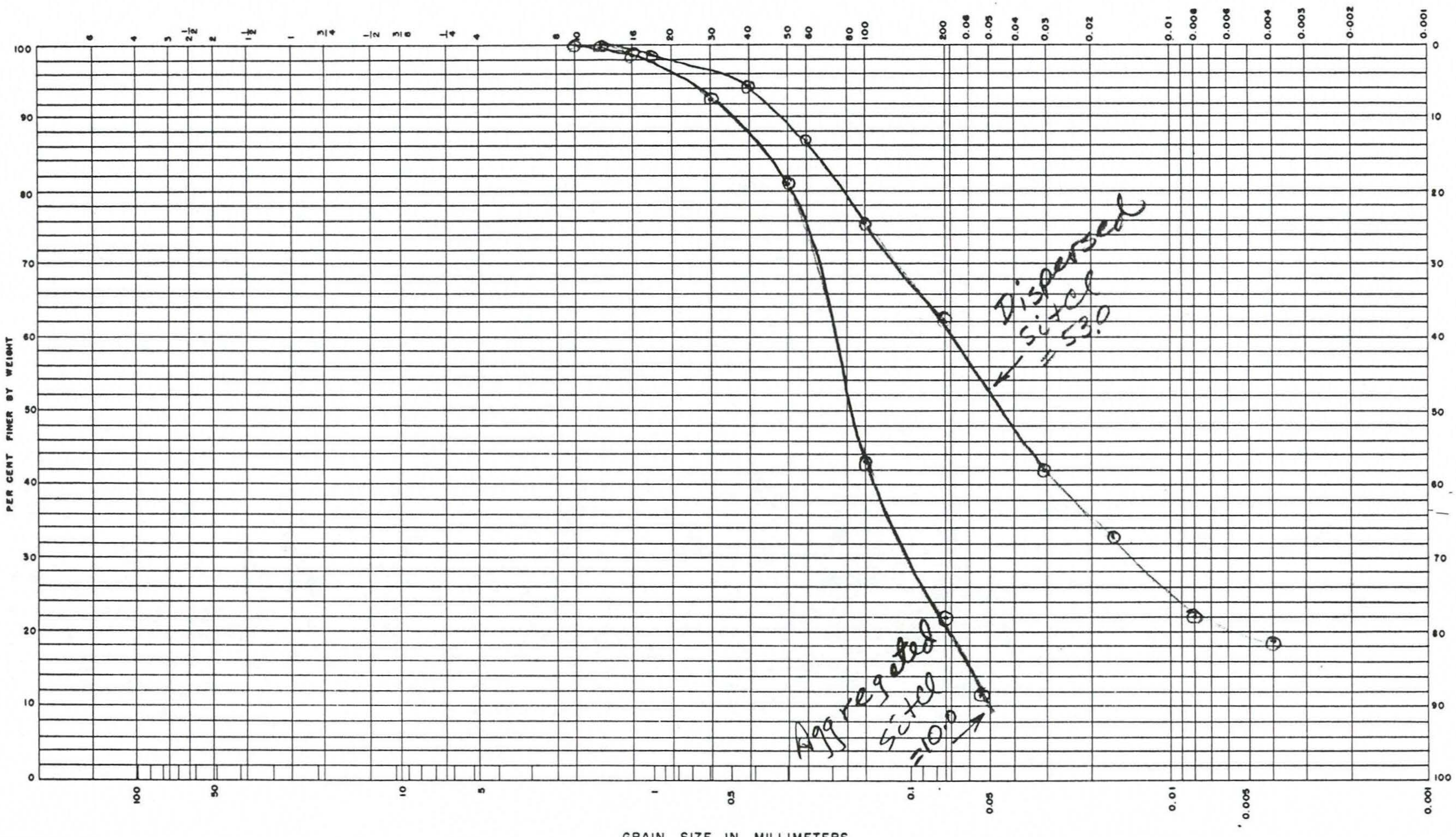
SOIL MECHANICS LABORATORY

GRADATION CURVE

BY______ LABORATORY NO.______
DATE______ FIELD NO.______

| SIEVE ANALYSIS | | HYDROMETER ANALYSIS |
|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH - U.S. STANDARD | GRAIN SIZE IN MM |

DITCHCAMP




| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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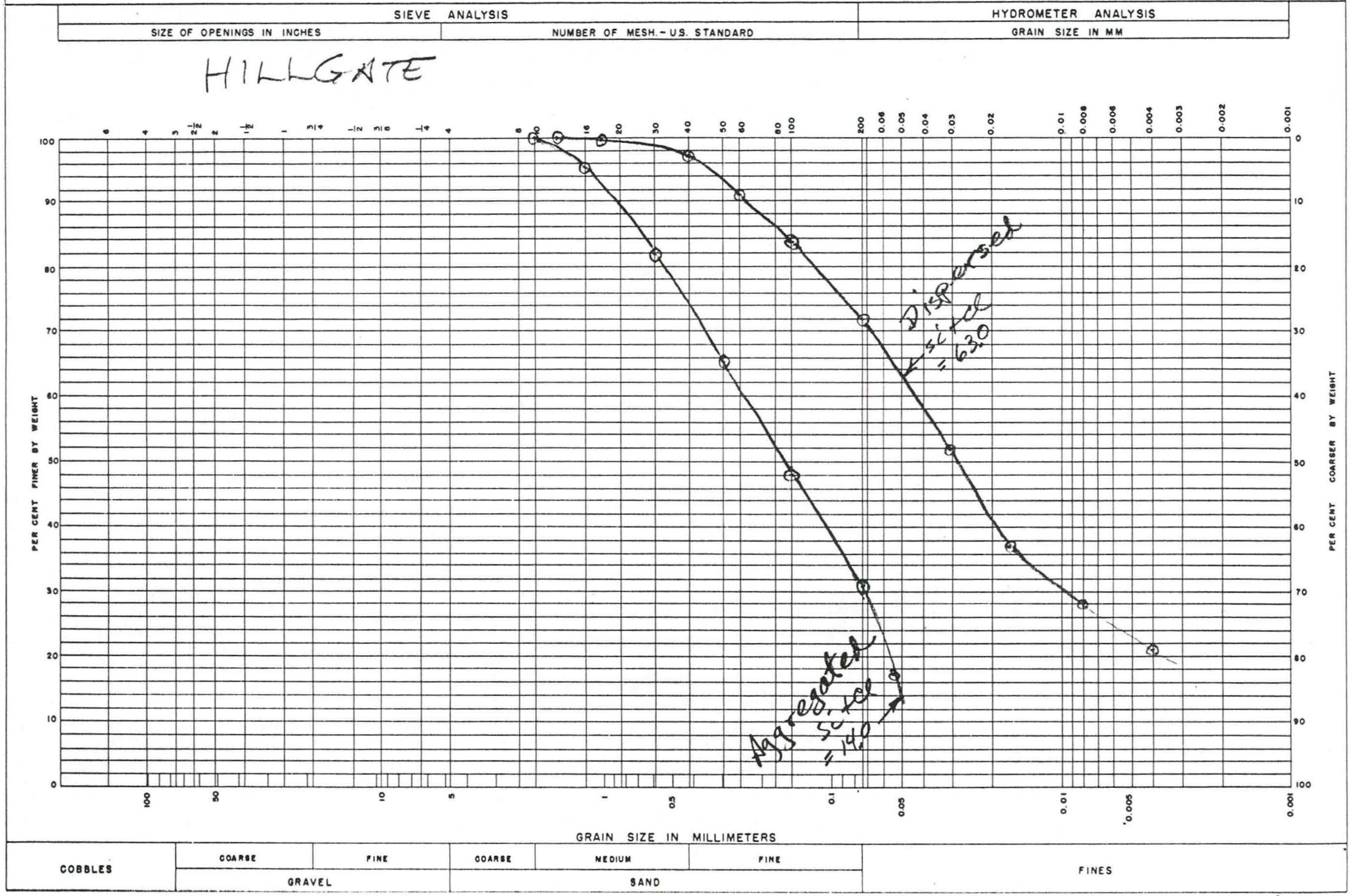
GRADATION CURVE

BY__________ LABORATORY NO.__________
DATE__________ FIELD NO.__________



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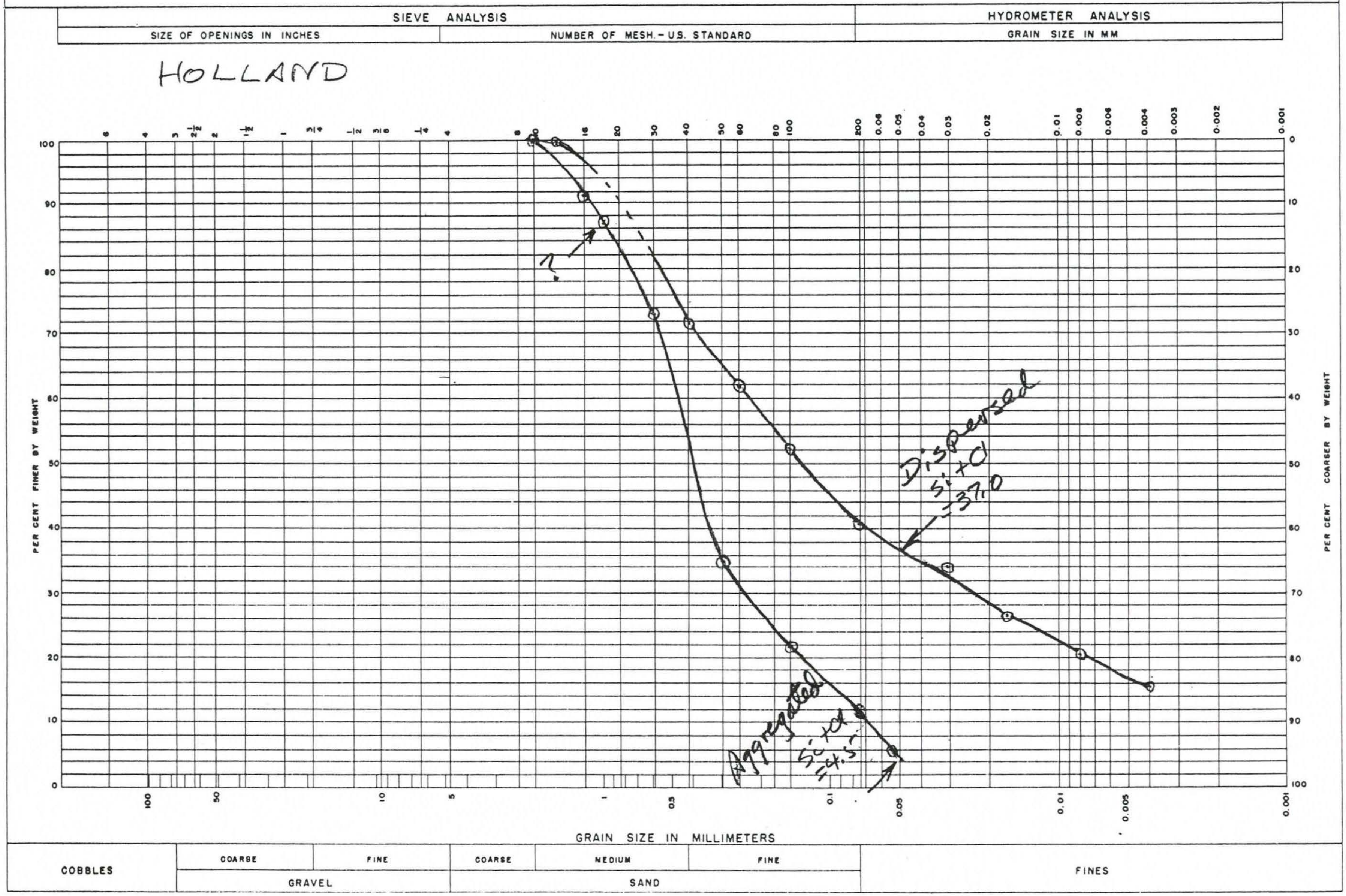
GRADATION CURVE

BY ______ LABORATORY NO. ______

DATE ______ FIELD NO. ______



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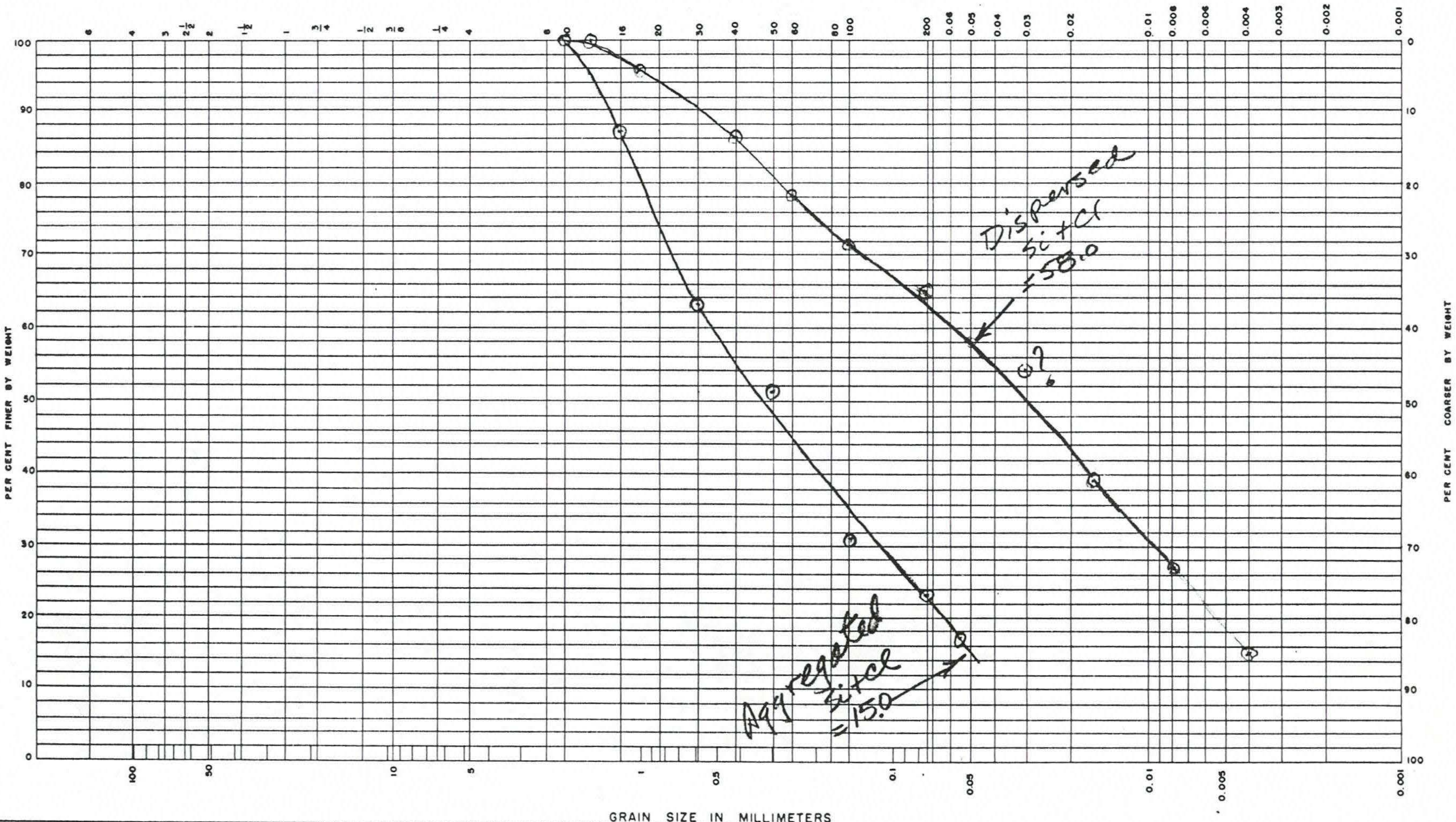
GRADATION CURVE

BY________ LABORATORY NO.________

DATE________ FIELD NO.________

| SIEVE ANALYSIS | | HYDROMETER ANALYSIS |
|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH - U.S. STANDARD | GRAIN SIZE IN MM |

HURLBUT




| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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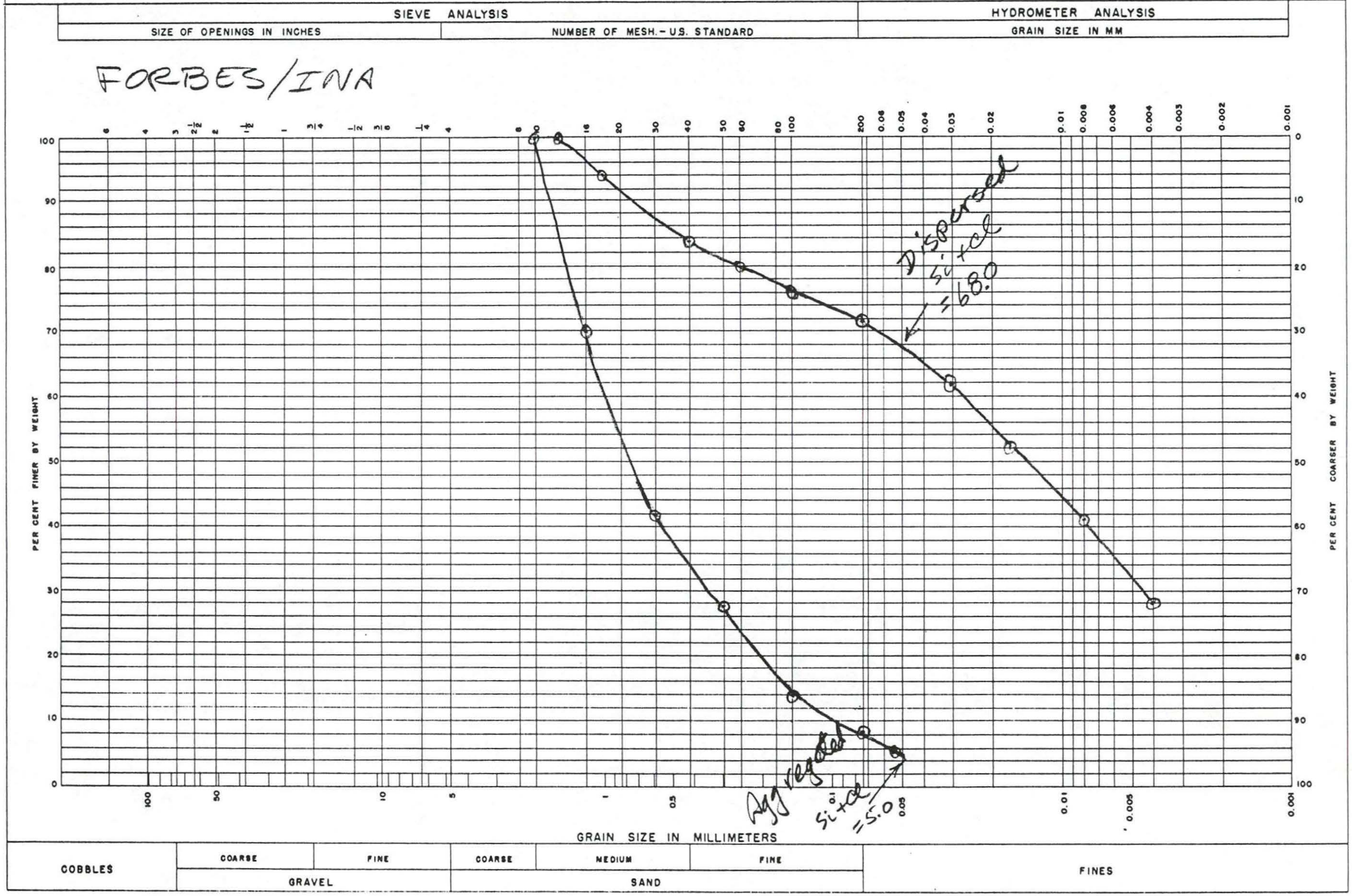
GRADATION CURVE

BY ______ LABORATORY NO. ______

DATE ______ FIELD NO. ______

FORBES/INA



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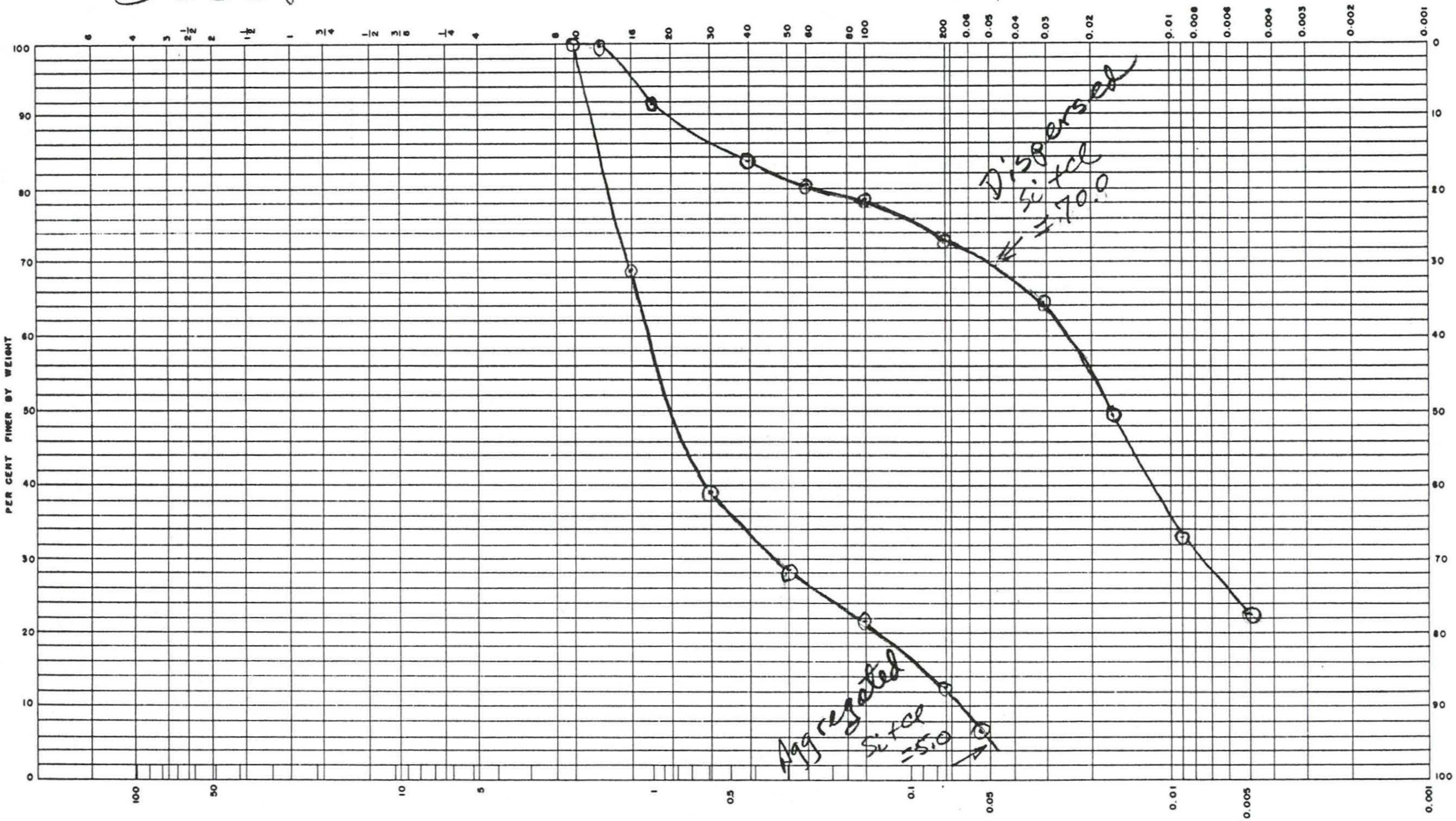
GRADATION CURVE

BY ______ LABORATORY NO. ______
DATE ______ FIELD NO. ______

| SIEVE ANALYSIS | | HYDROMETER ANALYSIS |
|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH - U.S. STANDARD | GRAIN SIZE IN MM |

JOSEPHINE




GRAIN SIZE IN MILLIMETERS

| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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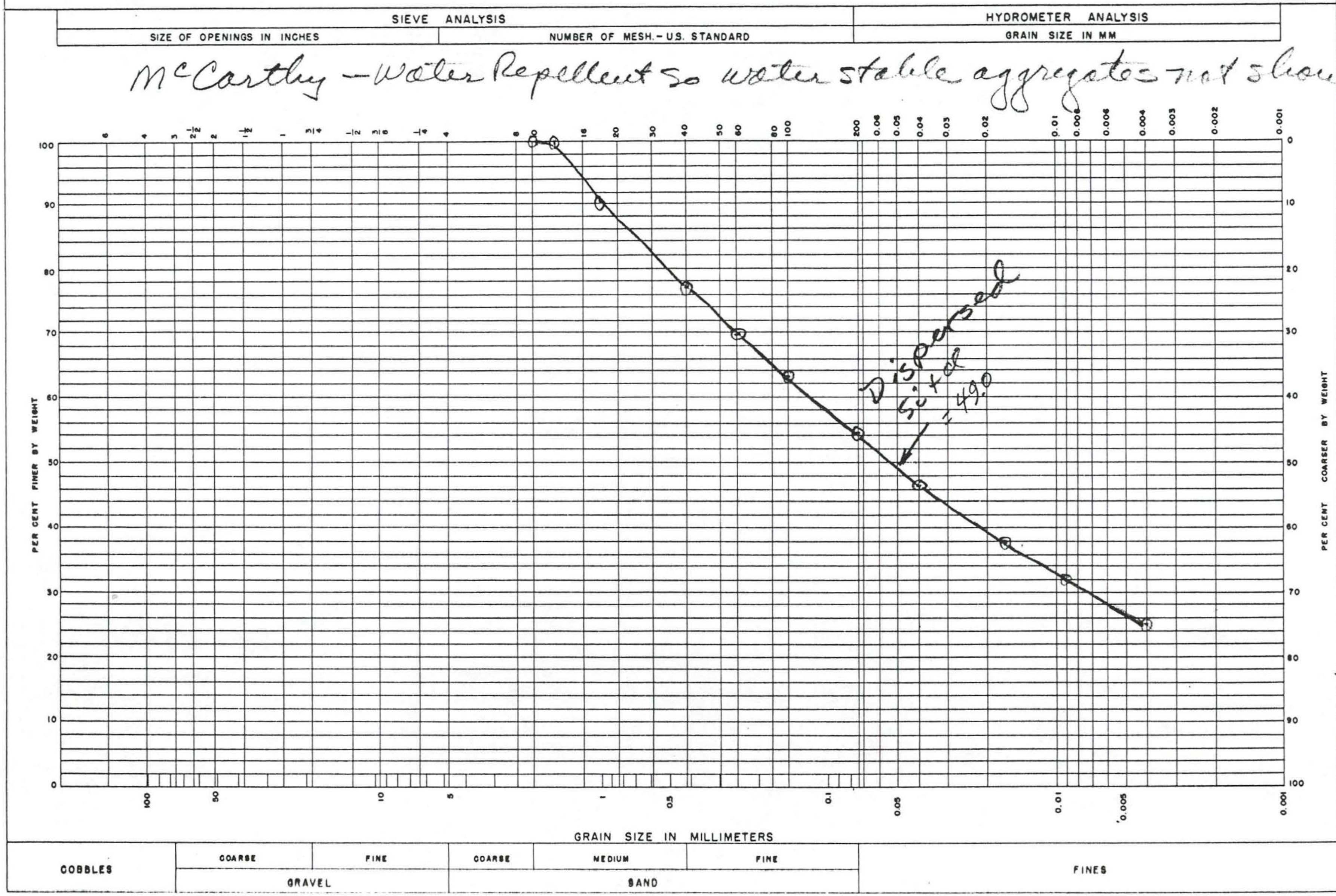
GRADATION CURVE

BY ______ LABORATORY NO. ______
DATE ______ FIELD NO. ______

McCarthy - Water Repellent so water stable aggregates not shown



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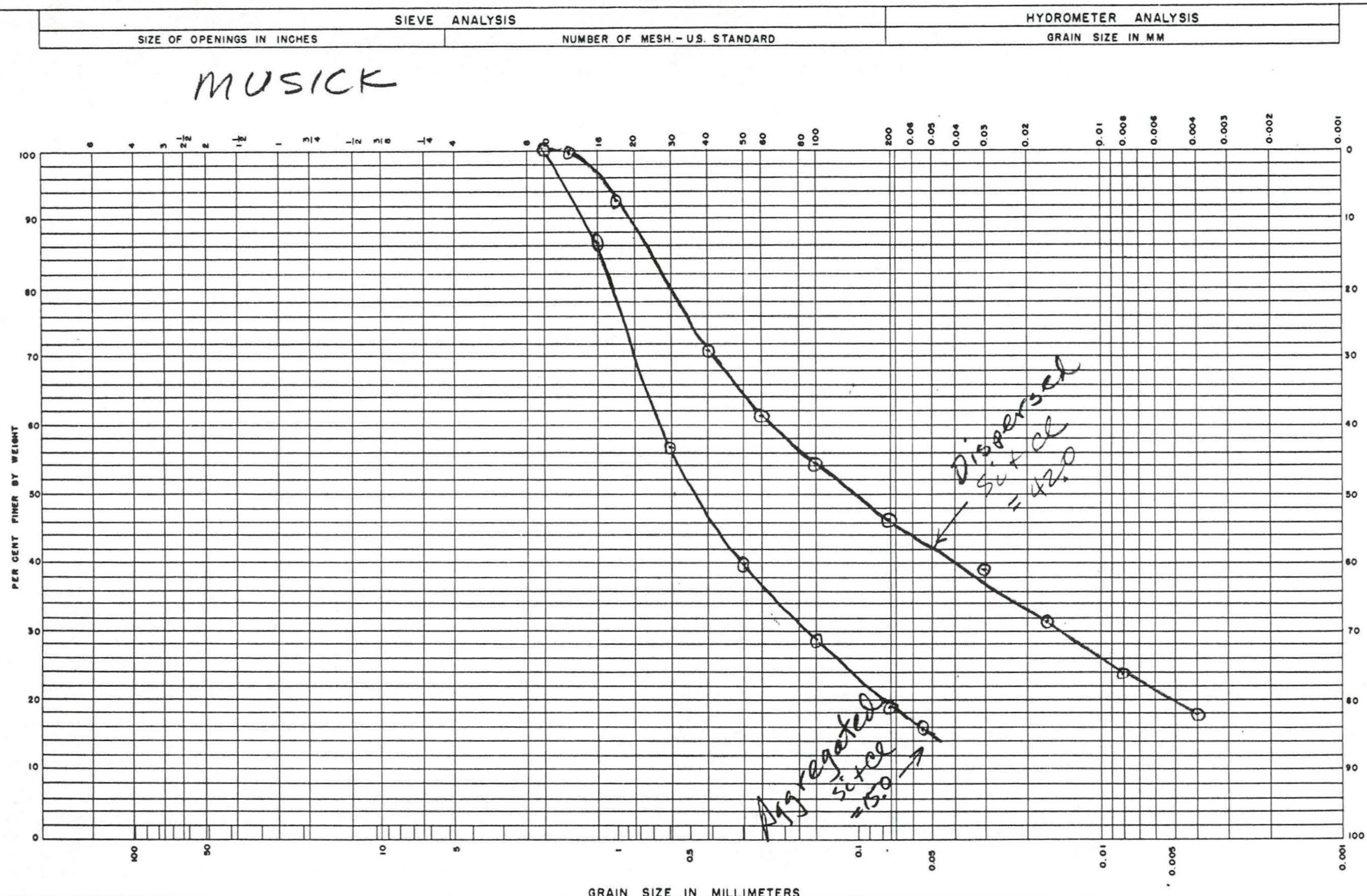
GRADATION CURVE

BY________ LABORATORY NO.________
DATE________ FIELD NO.________




| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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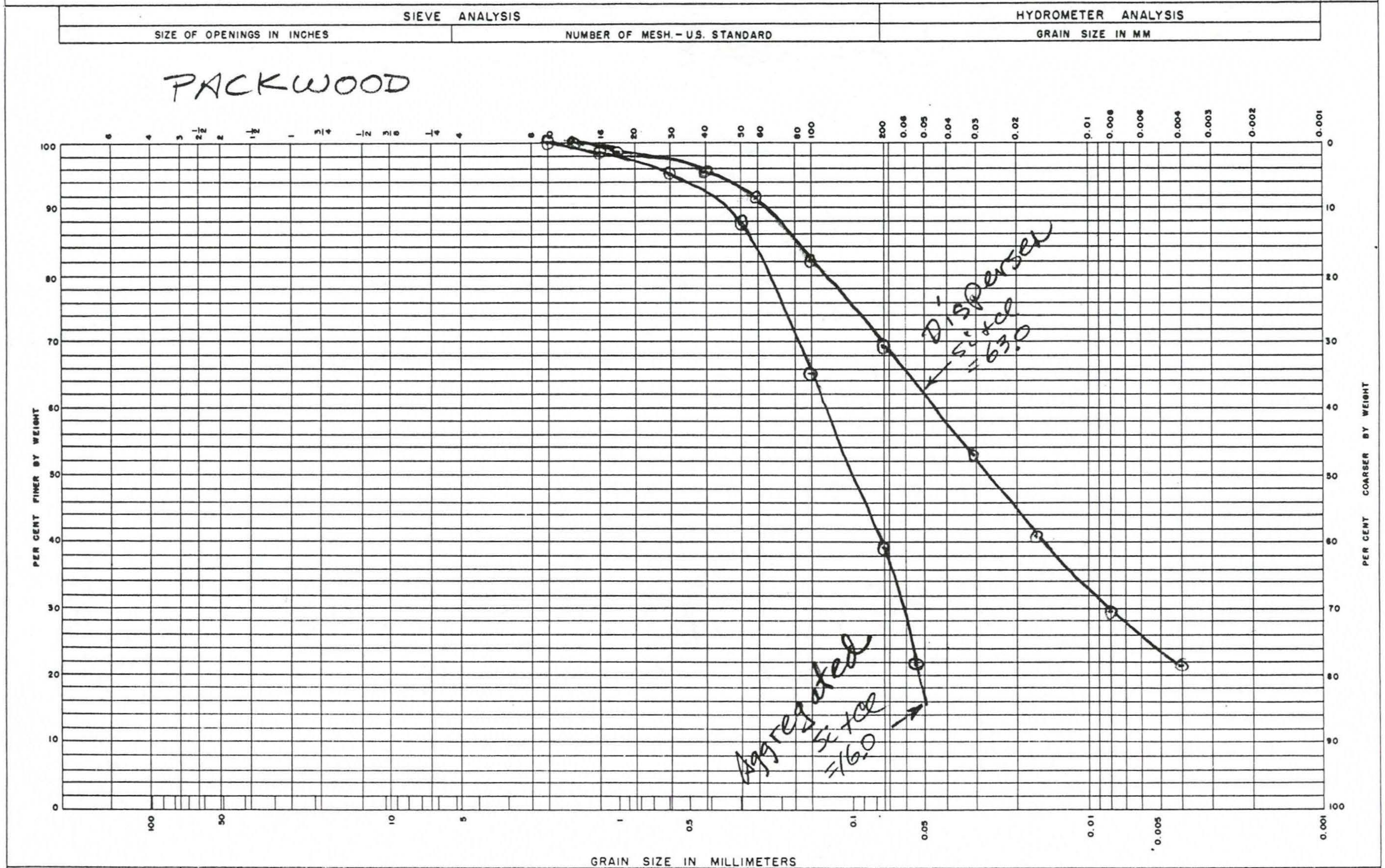


| COBBLES | GRAVEL | | SAND | | | FINES |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

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DATE________ FIELD NO.________

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|---|---|---|
| SIZE OF OPENINGS IN INCHES | NUMBER OF MESH – U.S. STANDARD | GRAIN SIZE IN MM |

WINDY Water Repellent so water stable aggregates not shown